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JOINT INSTITUTE FOR ADVANCEMENT OF FLIGHT SCIENCES

Program of Research in Flight Dynamics in the JIAFS at NASA-Langley Research Center

NASA Cooperative Agreement NCC1-29

Semi-Annual Status Report

December 1, 1995 - May 31, 1996

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Washington, DC 20052

OVERVIEW

The program objectives are fully defined in the original proposal entitled "Program of Research in Flight Dynamics in the JIAFS at NASA-Langley Research Center," which was originated March 20, 1975 and in the renewal of the research program dated December 1, 1995.

The program in its present form includes four major topics:

1. The improvement of existing methods and development of new methods for flight test data analysis,

2. the application of these methods to real flight test data obtained from advanced airplanes,

3. the correlation of flight results with wind tunnel measurements, and theoretical predictions.

The Principal Investigator of the program is Dr. V. Klein. Three Graduate Research Scholar Assistants (D. R. McDaniel, G. P. Greiner and L. V. Nguyen) also participated in the program.

SPECIFIC DEVELOPMENTS

Specific developments in the program during the period December 1, 1995 through May 31, 1996 included:

1. <u>Research on Methods for System Identification</u>.

A revised study on the modeling and estimation of aerodynamic parameters of an isolated wing or aircraft subjected to forced oscillations in the wind tunnel was completed. The purpose of this study was to develop a method for estimation of unknown parameters in mathematical models postulated for wind tunnel data from small amplitude oscillatory testing, and demonstrate this method in three examples. In the first example, the forced oscillatory data in pitch of a triangular wing are analyzed. The second examples uses the oscillatory data in roll of a model of the X-31 experimental aircraft. The third example deals with acceleration-in-sideslip data of a high incidence research model (HIRM). In this test, the model oscillates in sideslip at a specified angular velocity and amplitude. From the measured data, the aerodynamic derivatives corresponding to sideslip angle and its rate are calculated.

Using nonlinear least squares, an algorithm for aircraft aerodynamic parameter estimation from wind tunnel oscillatory data was developed. Models of an aircraft in one-degree-of-freedom, small-amplitude, harmonic motion included unsteady terms in the form of indicial functions. In formulating the analytical form of indicial functions for this type of data analysis two conflicting requirements had to be addresses: parameter estimation requires a simple model with a small number of parameters in order to insure their identifiability; on the other hand, a simple model will not completely explain the rich and complex phenomena at various scales associated with unsteady and separated flow during oscillatory or transient motion. The indicial functions were postulated as simple exponential forms where the unknown parameters included aerodynamic derivative, the exponent and multiplication term. It is important to realize that the model proposed in this work should be used in the analysis of experimental oscillatory data where the effect of frequency is considered at a given nominal angle of attack and Reynolds number. For different applications the proposed form of indicial functions should be reconsidered.

The results of this study will be presented at the High-Angle-of-Attack Technology Conference on September 17-19, 1996.

2. <u>Application of System Identification to Advanced High-Performance Aircraft</u>

A draft of a paper on "Aerodynamic and Thrust Vectoring Parameters of the X-31A Aircraft Estimated from Flight Data at Moderate to High Angles of Attack" for the High-Angle-of-Attack Technology Conference was completed. The purpose of this paper is to:

a) analyze a new set of maneuvers excited by the pilot and reanalyze the maneuvers using single surface excitation for obtaining estimates of stability and control derivatives within the angle-of-attack range from 10° to 70°,

b) discuss identifiability problems of various parameters and their effect on the accuracy of parameter estimates,

c) correlate the flight results with wind tunnel data and parameters obtained from the X-31 drop model test.

Maneuvers from eight flights were selected for aerodynamic model structure determination and parameter estimation. These maneuvers were initiated from trim conditions at altitudes between 6,000 to 9,000m and angles of attack between 10° and 70°. The pilot inputs were either pitch commands in the form of a single doublet or a combination of doublets, or roll and yaw commands in the form of simple doublets. The flutter test box allowed for separate excitation of all aerodynamic control surfaces. These inputs were in the form of multiple doublets. Maneuvers with pilot inputs were flow with thrust vectoring off (for the angles of attack less than 30°) and on. The single surface excitation maneuvers were realized only with thrust vectoring on.

Static and dynamic wind-tunnel tests were conducted in the 30- by 60-Foot Tunnel at NASA LaRC using a 19-percent scale model. Static tests covered a wide range of angles of attack and sideslip angles, with different positions of canard, flaperon and rudder. From these measurements, static stability and control derivatives corresponding to trim conditions at various angles of attack were evaluated. The dynamic stability derivatives were obtained from oscillatory tests conducted at various angles of attack, canard settings, and two amplitudes and frequencies of harmonic oscillations.

In preparation for the X-31A testing, an unpowered 27-percent dynamically-scaled drop model of the X-31 was built and tested at NASA LaRC. The results were taken from the existing reference.

The paper includes twelve main aerodynamic parameters in the vertical-force, pitching-moment, lateral-force, and rolling- and yawing-moment equations. These parameters are plotted against the angle of attack and compared with data from wind tunnel and drop model experiments. In addition, two thrust-vectoring parameters representing the thrust-vectoring effectiveness in pitch and yaw are also included. The effect of data collinearity, small excitation of aircraft response variables, and input form on the identifiability of each parameter is discussed.

The work also continued in a separate report dealing with identification of longitudinal aerodynamics and handling qualities parameters of the X-31A aircraft from flight test data. The estimated transfer function coefficients resulted in three important parameters, damping ratio, natural frequency and static gain associated with the longitudinal short-period motion of the aircraft.

3. <u>High Speed Civil Transport</u>

a) The desire to include dynamic elastic effects in the Reference H real-time simulation has been the main thrust of research for this period. To achieve this, the dynamic equations of motion using rational function approximation for the unsteady aerodynamics was coded in the DCB Reference H Matlab simulation. This implementation was then verified and preliminary results presented at the annual Reference H review in February. A Simulation Modification Request (SMR) was then presented to the real time simulation group for implementation. This will now be utilized in the last Reference H upgrade, Cycle 3, due in July.

The issue to have a continuous mass model was raised once again at the February review. With additional mass cases provided from Boeing the task of modeling the various fuel tanks was looked at again. It was then conclusively evident that the additional fuel mass models do not contain enough information to model the individual tanks. A memo was then prepared specifying the fuel mass model requirements for the next High Speed Research (HSR) aircraft due out in 1997.

b) Since the beginning of January 1996, the work on the Graphical User Interface (GUI) for the MATLAB/SIMULINK-based Reference H simulation has continued. During the first two months of the year, a large amount of time was utilized to adapt the existing portions of the GUI into a recursive function format which was seen to have many advantages over the script file format. By mid-February, the GUI was capable of trimming the Ref H (using the recursive function format) with limitations existing only on the user's choice of independent trim variables. A formal briefing as well as a 15 minute demonstration was conducted at the HSR - Guidance and Control annual review in late February.

Instead of proceeding with completion of implementing the linear model generation and nonlinear simulation tasks into the GUI, a decision was made to generalize the Ref H trim capability via the GUI. Up until then, modifying the current trim solution setup in terms of constraint assignment, independent variable choices, and control surface interconnections (outside of the GUI) required a fair amount of file manipulation. Some time was spent generalizing the trim task via the GUI. Currently, a user can set up any conceivable flight conditions, control linkages, independent variables, constraints, etc. and trim the Ref H in a matter of minutes. This implementation has been validated against original non-GUI check cases. In addition, the capability for the user to select among a number of output units is also available. Finally, the GUI is also now capable of writing output files, executable M-files, and loading/saving user-defined setups.